Introduction to SLAT

Seismic Loss Assessment Tool

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Quake Centre

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What is SLAT?

What is SLAT?

*S*eismic *L*oss *A*ssessment *T*ool

What is SLAT?

Seismic Loss Assessment Tool

The Big Question:

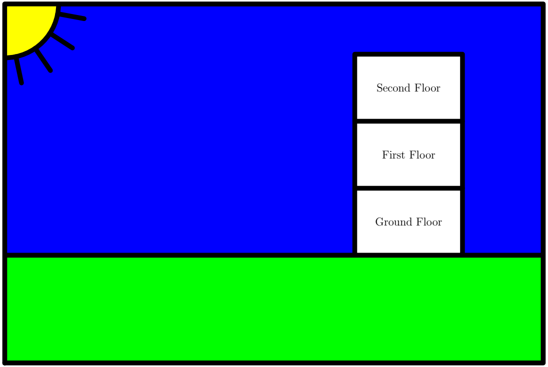
What is SLAT?

Seismic Loss Assessment Tool

The Big Question:

What is the cost of seismic activity likely to be, over the lifetime of the building?

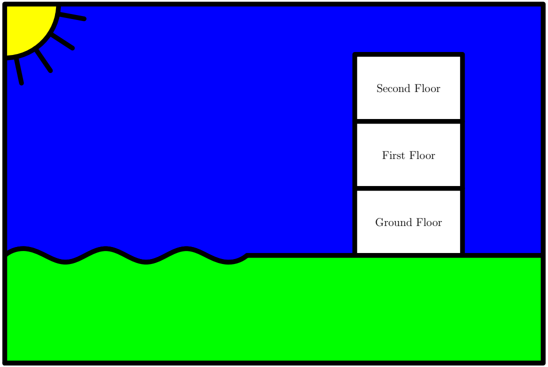
A Building



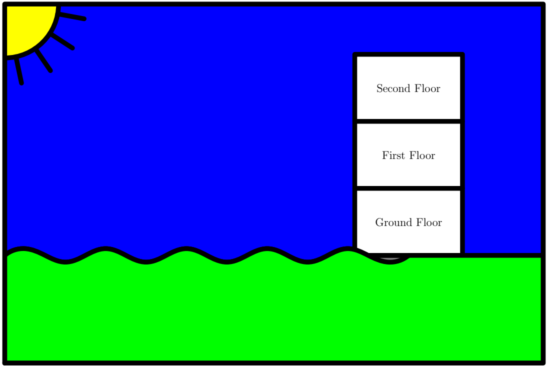
. . . peacefully minding its own business.

A Distant Rumble. . .

The Disturbance Generates Seismic Waves



The waves reach the building site



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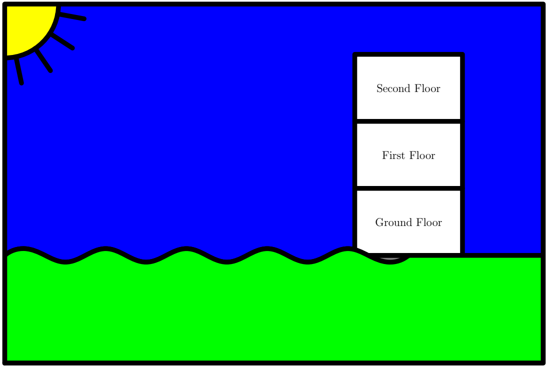
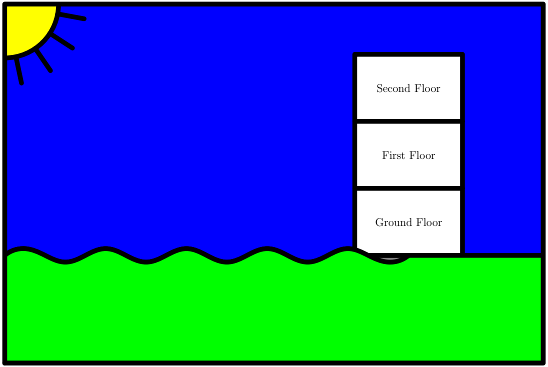


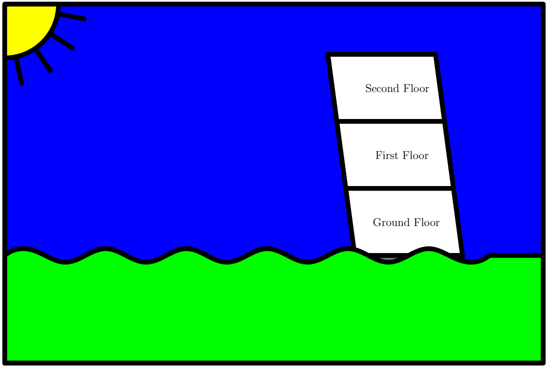
- Motion at the site is characterised by the spectral acceleration.

The waves reach the building site



- Motion at the site is characterised by the spectral acceleration.
- SLAT calls this the *intensity measure* (im).

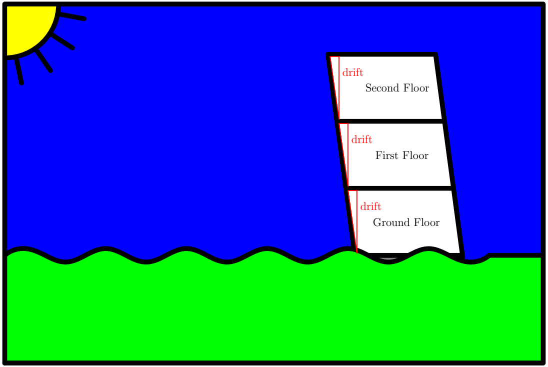
The building moves



Acceleration

Each level (including the base and the roof) experience acceleration.

Drift



When the floor and ceiling don't move together, we get inter-story drift.

Damage States

State	Description	Repairs	Demand	Cost

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DS1	Small cracks in GIB	Patch	0.0025	$ 35

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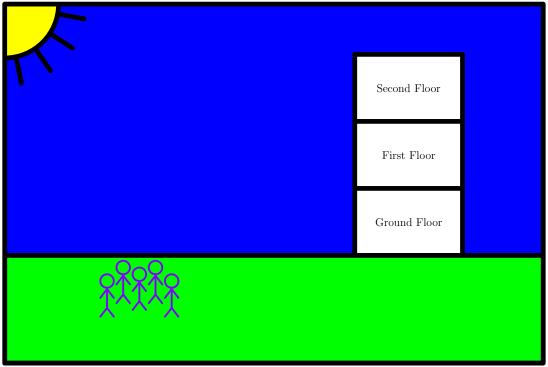
DS1	Small cracks in GIB	Patch	0.0025	$ 35
DS2	Large cracks in GIB	Replace GIB	0.006	$ 55
DS3	Damage to metal frame	Reframe	0.014	$130

Back to normal?



SLAT bases its calculations on:

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The Performance-Based Earthquake Engineering (PBEE) framework

From the Pacific Earthquake Engineering Research Center (PEER)

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$$\lambda(DV) = \int_{IM=0}^{\inf} \int_{EDP=0}^{\inf} \sum_{DS=1}^{n} G(DV|DS)|\Delta G(DS|EDP)||dG(EDP|IM)||d\lambda(IM)|$$

The Left-Hand Side

$$\boxed{\lambda(DV)} = \int_{IM=0}^{\inf} \int_{EDP=0}^{\inf} \sum_{DS=1}^{n} G(DV|DS)|\Delta G(DS|EDP)||dG(EDP|IM)||d\lambda(IM)|$$

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λ means 'annual rate of exceedence'.

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DV is the 'decision variable', which for `SLAT` is cost.

The Outer Integral

$$\lambda(DV) = \int_{IM=0}^{\inf} \boxed{\int_{EDP=0}^{\inf} \sum_{DS=1}^{n} G(DV|DS)|dG(DS|EDP)||dG(EDP|IM)|} |d\lambda(IM)|$$

$$COST|IM$$

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- Integrating over all possible accelerations

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- Integrating over all possible accelerations
- ..with respect to the rate-of-exceedance

The Inner Integral

$$\lambda(DV) = \int_{IM=0}^{\inf} \int_{EDP=0}^{\inf} \boxed{\sum_{DS=1}^{n} G(DV|DS)|\Delta G(DS|EDP)|} \, |dG(EDP|IM)||d\lambda(IM)|$$

$$COST|EDP$$

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$$\lambda(DV)=\int_{IM=0}^{\inf}\int_{EDP=0}^{\inf}\boxed{\sum_{DS=1}^{n} G(DV|DS)|\Delta G(DS|EDP)|}\,|dG(EDP|IM)||d\lambda(IM)|$$

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- Integrating over all possible demands

The Inner Integral

$$\lambda(DV)=\int_{IM=0}^{\inf}\int_{EDP=0}^{\inf}\boxed{COST|EDP}\,|dG(EDP|IM)||d\lambda(IM)|$$

- Integrating over all possible demands
- ..with respect to the probability of that demand, given a specific acceleration.

The Summation

$$\lambda(DV) = \int_{IM=0}^{\inf} \int_{EDP=0}^{\inf} \sum_{DS=1}^{n} \boxed{COST|DS} |\Delta G(DS|EDP)||dG(EDP|IM)||d\lambda(IM)|$$

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$$\lambda(DV) = \int_{IM=0}^{\inf} \int_{EDP=0}^{\inf} \sum_{DS=1}^{n} \boxed{COST|DS} \Delta G(DS|EDP)||dG(EDP|IM)||d\lambda(IM)|$$

- Summing over all possible damage states

The Summation

$$\lambda(DV) = \int_{IM=0}^{\inf} \int_{EDP=0}^{\inf} \sum_{DS=1}^{n} \boxed{C(OST|DS)} |\Delta G(DS|EDP)||dG(EDP|IM)||d\lambda(IM)|$$

- Summing over all possible damage states
- Cost of damage, weighted by the likelihood of that damage occuring at the given demand

Not So Scary Now

$$\lambda(DV)=\int_{IM=0}^{\text{inf}}\int_{EDP=0}^{\text{inf}}\sum_{DS=1}^{n}G(DV|DS)|\Delta G(DS|EDP)||dG(EDP|IM)||d\lambda(IM)|$$

Hazard Curve

$$\boxed{\lambda(DV) = \int_{IM=0}^{\inf} \int_{EDP=0}^{\inf} \sum_{DS=1}^{n} G(DV|DS)|\triangle G(DS|EDP)||dG(EDP|IM)|}|d\lambda(IM)|$$

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- Annual rate-of-exceedence of IM

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- Annual rate-of-exceedence of IM
- Use NZS 1170 to generate the *hazard curve*.

Demand Curves

$$\boxed{\lambda(DV) = \int_{IM=0}^{\inf}\int_{EDP=0}^{\inf}\sum_{DS=1}^{n} G(DV|DS)|\triangle G(DS|EDP)|}\,|dG(EDP|IM)|\,\boxed{|d\lambda(IM)|}$$

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- Probability curve of demand given IM

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- Probability curve of demand given IM
- Results of structural analysis

Fragility Function

$$\boxed{\lambda(DV) = \int_{IM=0}^{\inf} \int_{EDP=0}^{\inf} \sum_{DS=1}^{n} G(DV|DS)} |\Delta G(DS|EDP)| \boxed{|dG(EDP|IM)||d\lambda(IM)|}$$

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- Probability of each damage state given demand ('fragility curve').

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- Probability of each damage state given demand ('fragility curve').
- Stored in the SLAT component database

Cost Function

$$\boxed{\lambda(DV) = \int_{IM=0}^{\inf} \int_{EDP=0}^{\inf} \sum_{DS=1}^{n}} G(DV|DS) \boxed{|\triangle G(DS|EDP)||dG(EDP|IM)||d\lambda(IM)|}$$

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- Probability cost exceeding a given value, for each damage state ('cost function')
- Also stored in the `SLAT` component database

Required Data

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- Hazard curve

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- Demand Curves

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- Demand Curves
- Component Fragility Curves

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- Hazard curve
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- Component Fragility Curves
- Component Cost Functions
- Components in the building
- Mapping of Components to Demands

Demand Curves

Where do we get the demand curves?

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- Non-linear Response History Analysis

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  - Apply Corrections:

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Demand Curves

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- Simplified Approach
  - Equivalent Static Analysis
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  - Apply Corrections:
    - Non-linear effects
    - Higher-order effects

The Corrections

FEMA P-58

"Seismic Performance Assessment of Buildings"

The Corrections

FEMA P-58

"Seismic Performance Assessment of Buildings"

- From ETABS
  - Fundamental Period
  - Height of Each Story
  - Mass
  - Story Drift at design acceleration
  - Story Acceleration at design acceleration

Additional Information:

- Return Period
- Type of frame in each direction
- Constants from ASCE/SEI 7-10:

R	Response Modification Coefficient
I	Importance Factor
Ω_0	Overstrength Factor

Yield Strength

FEMA's simplified approach provides an estimate range for the yield strength:

$$\frac{1.5 S_a(T) W}{R/I} \leq V_y \leq \frac{\Omega_0 S_a(T) W}{R/I}$$

SLAT will do this calculation for you, and offer the middle of the range as a default value.

FEMA Corrections

The FEMA framework applies the following correction to drift (acceleration is similar):

$$\Delta_i^* = H_{\Delta_i}(S, T_1, h_i, H) \times \Delta_i$$

where:

- S is the strength ratio ($\frac{S_a(T_1)W}{V_y}$).
- T_1 is the fundamental period
- h_i is the height above ground of level i
- H is the total height of the building

FEMA Corrections

$H_{\Delta_i}(S, T_1, h_i, H)$ is computed from:

$$ln(H_{\Delta_i}) = a_0 + a_1 T_1 + a_2 S + a_3 \frac{h_{i+1}}{H} + a_4 (\frac{h_{i+1}}{H})^2 + a_5 (\frac{h_{i+1}}{H})^3$$

for $S \geq 1, i = 1 to N$.

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Consult FEMA P-58 for more details.

The Software

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With `SLAT`, you won't have to!

SLAT

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Demo

WebSLAT is installed on a virtual machine, which you'll be able to run on your own PC, using VirtualBox.

Let's have a look at it in action.